BAKING TESTS AND RESULTS OF A1050 DIAMOND EDGE GASKET

I. T. Huang#, C. C. Chang, H. P. Hsueh, G. Y. Hsiung, NSRRC, Hsinchu, Taiwan
J. R. Chen, NSRRC and NTHU, Hsinchu, Taiwan

Abstract

A1050 is a common and soft material, widely used in everyday life. It is machinable and cheap, which makes it a candidate for a gasket material [1,2]. In the case of sealing between disparate materials, treating the thermal expansion when the gasket suffers from baking is difficult. The clearance and the eccentricity between the gasket and the flange are also important; most leaks occur about 80 ~ 110 °C. The experimental apparatus comprised a vacuum chamber with six diamond-edge gaskets assembled, a turbo-molecular pump and an extractor gauge, illustrated in Fig. 1. The pre-baking torque for this gasket is 70 -- 80 kg cm; the rates of both heating and cooling are less than 40 °C per hour. The gaskets are baked repeatedly under the same conditions excluding the target temperature set for baking. A1050 diamond gaskets work well after baking at 120 ~ 140 °C; at temperature 170 ~ 180 °C, leaks sometimes appear on cooling. This paper presents the baking results of A1050 diamond-edge gasket and explains the cause of leaking after baking above 150 °C.

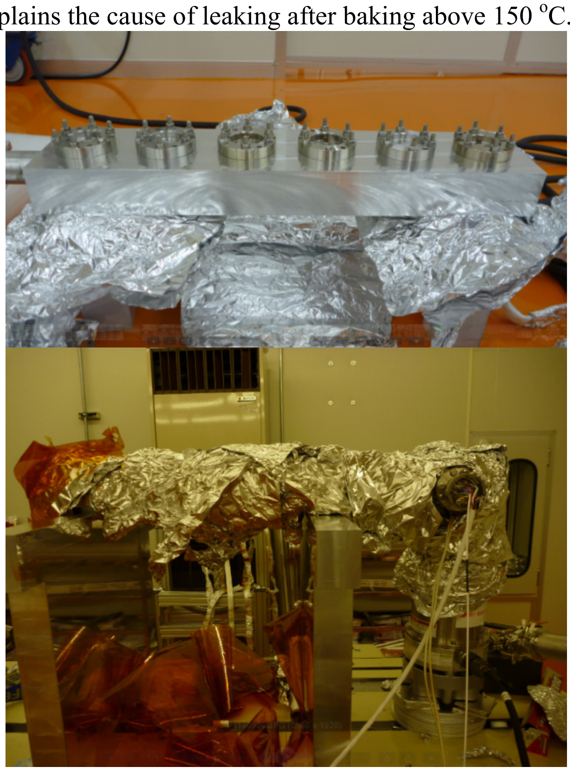

Figure 1: Baking system for Beam Position Monitor

INTRODUCTION

To achieve ultra-high vacuum, UHV, (< 10^{-9} torr), baking the target is the first choice. Under high-vacuum conditions, H_2O is the major constituent of the residual gas, for which the baking temperature is set above 100 °C. For Taiwan Photon Source, TPS, baking the vacuum chamber is set at 150 °C for 20 h. In the system to monitor the beam position, the gasket has a diamond-edged shape; the material is A1050. This gasket is clamped between a flange (SS316L) and a chamber (A6061). Upon baking, the disparate coefficients of thermal expansion result in a tension stress on the nuts. To re-torque the nut is necessary during cooling to 25 °C. This paper describes the experiment and results; those results reveal design criteria for a gasket seal, especially when treating the baking condition.

EXPERIMENT SETUP

An oil-free machined chamber has six holes of which each has a groove 1.9 mm deep in which the diamond-edged gasket is compressed. A dry pump connected with a turbo-molecular pump and an ion gauge are mounted in this baking apparatus. Heaters are wound around the chamber; a power supply applies a voltage to the heaters that induces a current flow therein. According to Ohm's law, resistive heat raises the temperature of the chamber; tuning the voltage then enables control of the temperature. The rates of both heating and cooling are controlled to be less than 40 °C per hour.

TORQUE

The dimensions of the diamond-edge gasket and the groove are shown in Fig. 2. The pre-torque is 70 kg cm; although only 40 kg cm is required to seal, Fig. 3, 70 kg cm provides superior performance through the baking process. Greater torque would also add a stress on the screws; in some cases, the nut would become stuck with the set screw, and make the torque unable to transport an axial force well. That condition would likely result in a non-uniform pressure and could be one reason for a leak. Use of a torque wrench is suggested, and with torque increased step by step (technically, 10 kg cm).

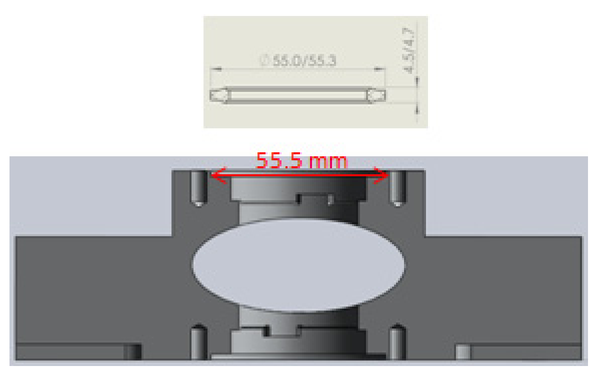

Figure 2: Geometry of the gasket and mating chamber

[#]huang.it@nsrrc.org.tw

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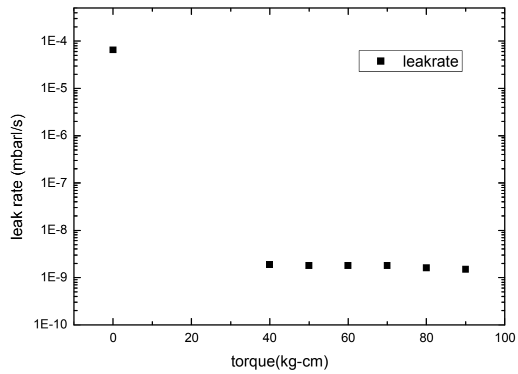

Figure 3: Leak rate vs torque of a diamond-edge gasket

HEATING POWER

Equation 1 states a relation between power and temperature, in which appear voltage V, resistance R of heaters, mass m of the entire system, specific heat capacity s and temperature change ΔT from the original one (here, 20 °C). If T_1 is the equilibrium temperature at V_1, as target temperature T_2 is known, the driving voltage V_2 can be deduced. The ultimate V_2 is tested several times. If the baked system is large, the system is divided into several parts; the same approach is used to discover each V_2. Not only heating but also cooling applies the same approach. Figure 4 shows one baking record of an experimental test.

$$P = \frac{V^2}{R}, \qquad and \qquad P = m * s * \Delta T,$$
$$\therefore \Delta T \propto V^2 \qquad \Rightarrow \qquad \frac{V_2^2}{V_1^2} = \frac{T_2 - 20}{T_1 - 20} \tag{1}$$

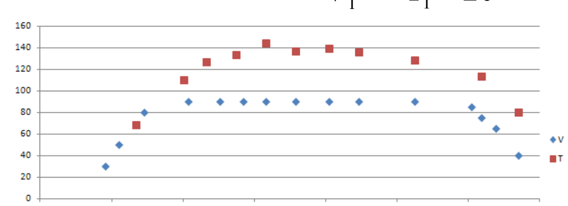

Figure 4: Temperature profile and its corresponding voltages

BAKING RESULTS

Several baking conditions have been tested including varying the baking temperature, locking torques and the height and outer diameter of the diamond edge gasket, listed in table 1. The first time, nuts readily lose their torque when cooling, especially about 110~120 °C, and after repeated baking beyond three times, even during the cooling, nuts are not readily moved forward. The reason is that every time a torque is imposed on a nut, the total effect on that nut makes it strong enough to compensate the torque lost by the thermal treatment. It is recommended to re-torque about 110~120 °C and 70~80 °C when the baking temperature is 150 °C. A higher baking temperature requires to re-torque at a higher cooling temperature. A simple way to estimate the temperature at which nuts must be locked is to divide ΔT by three; 1/3 ΔT and 2/3 ΔT drops correspond to the first and second temperatures at which nuts are supposed to be locked.

Another risk of baking at high temperature is the expansion of the diamond-edge gasket, especially the outer diameter. A few cases show that, upon baking and cooling, a compressed gasket interferes with the chamber, shown in Fig. 5. This condition is ascribed to not leaving sufficient clearance for thermal expansion. A soft gasket bearing axial pressure and then subjected to baking would not deform as much as one that has not been through axial pressure. According to a rough estimate, 70 kg cm corresponds to 500 kg tension axial load per nut. Two outer diameters of gaskets were tested. The smaller outer diameter works well, even for a baking temperature about 180 °C. Altering the total height of the gasket behaves almost the same, as long as sufficient height is designed for compression.

Applying a larger torque on nuts (above 100 kg cm) typically renders a nut stuck with a screw. In most cases, its real axial load is not the same as others. Compared with 70 kg cm, 100 kg cm has the advantage of less worry about torque decreasing after baking and cooling. The remaining torque might still seal but with a greater rate of slight leaks than at 70 kg cm. An obvious phenomenon is that it is accompanied by a stuck nut, which seldom happens in cases with 70 kg cm; 70 kg cm is more reliable than 100 kg cm or even greater.

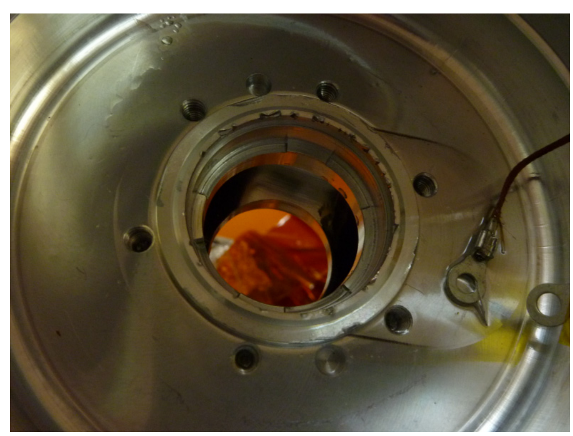

Figure 5: Gasket become severely stuck with the chamber through the baking test

Table 1: Parameters of Baking Experiments

Torque /kg cm	Baking T /°C	OD /mm	Height /mm
70	140-150	55.3	4.5
80	150-160	55.0	4.7
90	160-170	N	N
100	170-180	N	N
110	>180	N	N

DISCUSSION

In all tests, a leak is classified to arise from three main causes -- gasket dimension, screws and nuts, and conditions of the sealing surface [3].

The original gasket has width 55.3 mm as outer diameter; the groove has width 55.5 mm. Leaving 0.2 mm to absorb thermal deformation and to control the eccentricity of the angle of the diamond-edge gasket is suitable for every occasion of use, but, according to experimental results, not having enough space for radial deformation seems to result in poor sealing. Not only the thermal deformation but the pre-torque are believed to promote the radial deformation. To avoid a leak arising from this situation, the outer diameter of the gasket is altered to 55 mm, and the inner diameter is decreased to control the eccentricity.

In this system for the Beam Position Monitor, a flange like 35 CF and M6 set screw and nuts are used. The thread holes are machined directly on the aluminium chamber. The friction between the nut and the screw would affect the magnitude of the axial tension load of the nut. If every nut has varied friction to its mating screw, then every nut transfers a different axial load. Leaks might cause from a non-uniform load distribution around the sealing surface. Nuts readily become stuck, and leaks likely occur with greater torque. Equation 2 states the relation between the torque and the axial load of the nut.

The surface condition is not easily measured; only a few cases show that it might have an influence on the surface quality of both the diamond-edge gasket and the chamber. The real reasons are unknown, but, in actual experience, changing another gasket would solve this problem. Different from other cases, it generally occurs before baking, but, once it happens, there is a large risk of leakage after baking and cooling. One feasible way to settle this problem is to keep the torque of each nut at its original value when cooling begins.

$$T = c\,D\,F \tag{2}$$

T: Torque

c: Friction coefficient depends on conditions

D: main diameter

F : fastened axial load

SUMMARY

Diamond-edge gasket A1050H14 is used for the TPS BPM. Its small sealing torque is attractive, and it is simple to machine. The machining quality of the angle of the diamond-edge gasket is important and a smooth rounding of 0.2-0.3 mm is required. Pre-torque 70 -- 90 kg cm is acceptable, and a small torque would face a problem of insufficient fastening load to resist thermal tension. In contrast, a large torque would damage the screw and nut, and slight leaks appear more often than with less torque. To use a gasket of this kind as an interface between unlike materials, the load distribution around the sealing surface that is strongly dependent on the positions of the thread holes and the imposed load is crucial, particularly when used in a baking system. An unequal load distribution could unfortunately not be examined directly; it arises with every move for assembly. Care is essential at every step, including good surface condition of parts, adequate tools, reasonable dimensions of parts etc. Gaskets of this kind are also applied in TPS 24 cells that undergo baking at 150 °C. The ultimate pressure is about 10^{-11} torr with IP and NEG activated. Figures 6 is a pumping curve; Fig. 7 shows the RGA spectrum corresponding to one of the TPS 24 cells after baking. A gasket of this kind could be baked repeatedly, only requiring to recover its original torque equally on each nut.

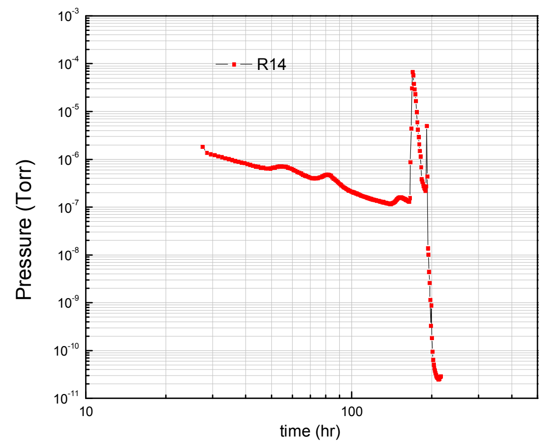

Figure 6: TPS, one cell pumping curve

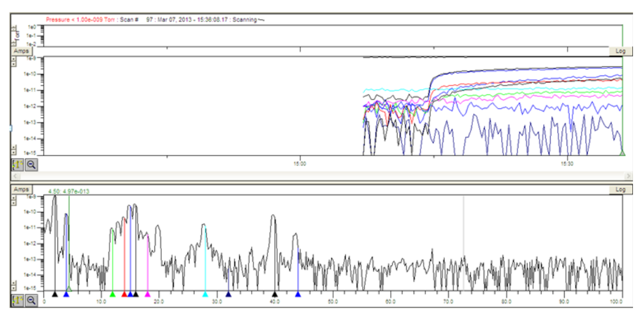

Figure 7: Spectrum of residual gases

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